REINFORCED WALL STRUCTURE FOR BLAST PROTECTION

Related Applications

This application is a continuation-in-part of my co-pending U.S. Provisional Application Serial Numbers 60/436,540 and 60/436,543, both filed December 27, 2002.

BACKGROUND OF THE INVENTION

The present invention relates to methods and constructions for protection of the contents of an enclosed space against damage caused by flying debris. More particularly, the present invention relates to methods and constructions for walls and ceilings for protection against natural and unnatural damaging forces. Natural forces may include, but are not limited to, earthquakes, fires, and high winds such as caused by tornadoes and hurricanes. Unnatural forces may include, but are not limited to, accidents involving boats, cars, planes or other vehicles, and explosive blasts such as caused during war or by terrorist attacks.

The present invention has particular application to protecting structures against bomb effects. Accordingly, the present invention is described herein with particularity to the protection of building walls against bomb effects. However, the present invention also has application to protecting other structures such as cargo containers, vehicles, machinery, etc. Accordingly, the phrase "wall structure" is used herein in the broadest sense to include any structure for protecting occupants and things.

The bomb has long been a favored weapon of terrorists' intent on killing people, destroying property or disrupting civil operations. Since the bombing of the Khobar Towers in Saudi Arabia in 1996 and the September 11, 2001 terrorist attack on the American Pentagon and World Trade Center, an intensified focus has been made to improve buildings' resistance to blast effects.

Little can be done to prevent damage to persons or objects who suffer a direct impact from the blast. However, a significant fraction of the damage to persons or properties can be reduced to those persons and objects that do not suffer a direct impact. One of the greatest causes of damage from an explosive attack comes from fragmentation, where pieces of walls, windows, equipment and other heavy objects fly at high speeds, which results in extensive injury and death. According to some estimates, fragmentation causes up to 80% of the casualties during a building failure.

A key tactic to defeating the threat of terrorist explosions is to insure that the wall is reinforced to survive a bomb blast without breaking apart and contributing to the fragment problem. The typical approach is to add strength and mass to the wall, usually using concrete and steel. Such "fortress" approaches are difficult to implement, are time consuming, are prohibitively expensive, and add significant weight so as to be prohibitive for most existing structures.

In 1999, the U.S. Air Force research laboratory began evaluating the use of elastomeric polymers applied to building walls for rapid and cost effective blast protection. An elastomeric coating, a polymer typically used for truck bed liners, was sprayed upon an 8' x 8' concrete wall. The concrete block previously found to fail at 2 - 4 psi pressures, withstood testing at 80+ psi blast pressures. The tested wall experienced large deflections during blast testing. However, the wall remained in place and persons outside the immediate blast injury would have remained safe.

Additional attempts have been made to reinforce existing walls. For example, several U.S. patents including U.S. Patent Nos. 6,212,840 and 5,763,043 describe reinforcing wall structures using fabrics, such as carbon fiber, mylar, fiberglass or aramid materials such as Kevlar™. Fabrics or grids made of these materials are adhered to a wall using binding agents such as epoxies, mixed resins, glues, rubber and many others. Additional retrofit attempts to reinforce existing walls have included the use of thermosetting adhesives between the reinforcing structure and the underlying wall. Also, geotextile fabrics and laminate sheets have been used as curtains to catch fragmentation and to reinforce wall structures. Even rigid plastic foam insulation boards have been applied to concrete or other wall materials for blast protection.

Unfortunately, each of the previous attempts to reinforce wall structures have suffered from significant drawbacks. For example, material curtains of geotextile materials and the like must be attached to a wall using bolts or brackets which can degrade the structural integrity of the wall structure. One key element to the retention of fragmentation is to provide ductility to the reinforcing wall structure. Unfortunately, reinforcing fabrics made of carbon fiber and/or aramid

provide high strength but little elongation. Accordingly, most fabrics and grid structures are too rigid to provide sufficiently elastic properties to deform under blast conditions so as to absorb much of the blast energy. An attempt to overcome this disadvantage is described in U.S. Patent No. 6,212,840 which discloses a thread which is woven in a manner to provide increased stretch. However, still additional ductility is desirable for blast protection.

Elastomeric polymers tend to suffer from diminishing returns as the elastomeric covering of a wall is increased in thickness. In particular, the thicker the elastomeric covering, the greater the outside radius of the material when deformed during blast conditions. To use an analogy, a single piece of paper bends easily; however, a hundred sheets adhered together do not. Similarly, the thicker the elastomeric layer, the more prone it is to fracture under blast conditions.

Still an additional disadvantage of the prior art reinforcement systems is that they do not provide the general appearance of a typical building wall. Instead, the outer elastomeric layer of the reinforcing wall structure is presented to the building occupants, appearing like a plastic covering. Moreover, sprayed-on elastomers tend to exaggerate surface imperfections, while trowel-on and roll-on applicators are difficult to apply with a consistent thickness. To create an aesthetic appearance, a texture can be machined into the elastomer using handheld or powered tools. These typical texturizing techniques produce a fine bumpy finish much like course sandpaper. The texturized elastomer may be acceptable to some architects and designers, but lack the quality demanded by many. Further, it is difficult to adhere wallpaper or paint to elastomer layers.

Attempts have been made to eliminate the unsightly appearance of the elastomer-covered walls, such as by covering the walls with additional building materials. Unfortunately, the additional building materials reduce the dimensions of the room and are also prone to fragmentation under blast conditions. Accordingly, prior art attempts, though achieving significant improvement in a wall's ability to withstand a bomb blast, still suffer from significant disadvantages.

Thus, there is a significant need for an improved reinforced wall system which can be used for both initial fabrication of a wall or for retrofitting an existing wall structure.

It would also be advantageous to provide an improved reinforced wall structure which provides improved blast protection.

It would still be an additional advantage to provide a reinforced wall structure which provides improved elastic properties.

It would be another advantage to provide a reinforced wall structure that reduces the brittleness typically found when increasing the thickness of a elastomeric layer upon a wall.

Further, it would be advantageous to provide a reinforced wall structure which would reduce the propensity of a fire to spread caused by a bomb blast.

Finally, it would be advantageous to provide an improved reinforcing wall structure which provides a conventional drywall texture without requiring an additional layer of conventional building materials.

SUMMARY OF THE INVENTION

The present invention addresses the aforementioned disadvantages by providing an improved reinforced wall structure for withstanding blast effects. The reinforced wall system includes an underlying wall substrate. The wall substrate may be any wall structure known to those skilled in the art such as brick, concrete, wood, reinforced drywall, and other wall structures that can be determined by those skilled in the art. The wall substrate may also include plastic, metal or fiberglass sheets, such as where the wall substrate forms a panel of a vehicle, cargo container or the like. The wall substrate is then covered with a reinforcing wall covering.

The reinforcing wall covering may be constructed in various manners depending on the various threat level to the wall and based upon the potential level of blast effects which the wall may experience. In a preferred embodiment, the wall covering includes a first layer of elastomer applied to the wall substrate. The elastomeric layer may be selected from various materials known to those skilled in the art. For example, suitable elastomeric materials include extruded thermoplastics, polyurea, polyurea-urethane, polyurethane, and mixtures thereof. The elastomeric layer may be applied by numerous means including spray or dip application or with trowel-on or roll-on applicators. However, air-less high pressure heated spray gun application is

considered best for providing an expedient and inexpensively applied layer of elastomeric material to building walls. Suitable spray systems include the Graco™, Foam Cat™, and Glasscraft™ dual component dispenser.

A reinforcing grid of strands is then applied to the first elastomeric layer. The grid of strands includes vertical and horizontal strands made of various reinforcing materials known to those skilled in the art. Preferably, the grid is made of one of the aramid materials such as Kevlar™ or Twaron™. Alternatively, the grid may be constructed of fibers made of carbon fiber, rayon, nylon, polyester, steel, or of numerous other materials as can be selected by those skilled in the art. The grid may also be made of combinations of the various materials which may be constructed including traditional vertically extending "warp" threads and horizontally extending "weft" threads. Alternatively, the reinforcing grid may include fibers which are helically woven or cross woven to provide additional elasticity. Preferably, the minimum spacing between strands is equal or greater than the diameter of the strands themselves.

In a preferred embodiment, the reinforcing grid includes horizontally and vertically extending strands which include an elastic central core wrapped by helically woven aramid fibers. Preferably, the threads' elastic cores are constructed of elastic materials such as spandex, nylon, rubber or other significantly stretchable material. These vertically and horizontally extending cores are then wrapped by a Dupont Kevlar™ or Teijin Twaron™ brand aramid in helical manner similar to the outer wrapping of a bungee cord. Advantageously, the elastic cord/helically wrapped aramid composite strands provide a highly elastic grid for absorbing the

energy from a blast effect. Preferably, the outer aramid threads are wrapped at an angle relative to the elastic core so that the elastic core and aramid threads reach their maximum elongation simultaneously prior to rupturing.

The preferred reinforced wall system includes a second elastomeric layer applied over the reinforcement grid. Again, the elastomeric layer is preferably applied using a spray application of any of numerous materials known to those skilled in the art. Still additional elastomeric layers may be applied to provide additional protection to the wall substrate. However, preferably, a release agent is applied between immediately adjacent elastomeric layers. The release agent may be any of numerous low adhesion materials such as teflon, silicon, grease, or oil based materials which reduce the adherence between elastomeric layers.

With reference to the preferred reinforcing wall covering, the release layer is preferably sprayed upon the second elastomeric layer leaving the periphery of the wall uncovered by the release agent. In another embodiment, the release agent is applied on the perimeter of the underlying elastomeric layer leaving only the middle region of the elastomeric layer exposed. An elastomeric layer is then applied over the release agent. Though the elastomeric layer will adhere minimally to the release agent, the elastomeric layer is held in place primarily due to its adherence directly to the underlying second elastomeric layer where the release agent is not present.

By separating the second and third elastomeric layers with a release agent, the third elastomeric layer is allowed to substantially "float" atop the second layer. In the event of a bomb blast or other violent environmental activity in the area, the second and third elastomeric layers will shear where the release agent has been applied. In similar manner to a phone book withstanding greater bending than a wood beam, the separation of elastomeric layers allows the layers to deform independently so as to withstand greater deformation without fracturing or tearing.

Where the wall appearance is of concern, preferably the third elastomeric layer is modified to provide a drywall texture. To this end, preferably the last few millimeters of the elastomeric layer are applied with an aggregate mixed into the elastomeric material to provide a slightly bumpy surface. The aggregate may consist of sand, walnut shells, metal fragments, or mixtures thereof having a grit size between 16 grit - 30 grit, though alternative aggregate sizes can be selected by one skilled in the art. The aggregate is added to the elastomer to provide a surface profile having enhanced adhesion properties for attachment of a paint, intumescent, spackle or other layer. Moreover, the aggregate provides the underlying layer with an appearance having greater similarity to that of a traditional wall.

An alternative method to providing a drywall-like finish can be accomplished by applying a modified spackle to the outer elastomeric layer. The modified spackle preferably includes a mixture of water, limestone and acrylic copolymer which can be applied using traditional trowel-on or roll-on techniques to cover the entire underlying elastomeric layer. Alternatively, the

modified spackle of water, limestone and acrylic copolymer can be applied to an elastomeric surface which has incorporated an aggregate to provide the most realistic drywall-like appearance.

Finally, preferably the reinforced wall system includes an outer fire retardant coating. The fire retardant coating may be a conventional fire retardant paint. However, preferably the outer coating is an intumescent topcoat which is approximately 20/1000" thick. Suitable intumescent materials include those supplied under the trade names Firefree 88™ and CKC F-268™. Alternatively, the intumescent material may be mixed with the modified spackle to provide an outer intumescent char forming covering to improve fire and heat resistance to the underlying wall structure.

Variation of the reinforced wall system may be made without departing from the spirit and scope of the invention. For example, depending on various factors such as the degree of threat of destructive force, installation costs or importance of building occupants and materials, additional layers of elastomeric materials, release agents, reinforcement grids, and intumescent compounds may be added to the reinforcing wall covering. Alternatively, where blast protection is of lesser concern, one or more layers of elastomeric materials, reinforcement grid, release agents or intumescent materials may be removed.

It is thus an object of the present invention to provide an improved reinforced wall system which can be used for both initial fabrication of a wall or for retrofitting existing wall structures.

It is an additional object of the present invention to provide an improved reinforced wall structure which can provide improved blast protection.

It is still another object of the present invention to provide an inexpensive and aesthetically pleasing wall structure having improved reinforcing properties.

These and other further advantages of the present invention will be appreciated by those skilled in the art upon reading the detailed description which follows with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective drawing the application of an elastomeric coating upon a reinforcing grid of the present invention;

Fig. 2 is cut-away side view of a first preferred embodiment of the reinforced wall system of the present invention;

Fig. 3 is cut-away side view of a second embodiment of the reinforced wall system of the present invention;

Fig. 4 is cut-away side view of a third embodiment of the reinforced wall system of the present invention;

Fig. 5 is a perspective view of a preferred strand for a grid of the present invention including fibers wrapped around an elastic core;

Fig. 6 is a perspective view of a preferred grid of the present invention including strands having fibers wrapped around an elastic core; and

Fig. 7 is a side depiction of a high-pressure heated dual component sprayer for applying an elastomeric coating of the reinforced wall system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

While the present invention is susceptible of embodiment in various forms, as shown in the drawings, hereinafter will be described the presently preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the invention, and it is not intended to limit the invention to the specific embodiments illustrated.

With reference to the figures, the reinforced wall system 1 of the present invention includes an underlying wall substrate 3 . The wall substrate may be any type of conventional building support or enclosure such as a wall, ceiling, floor, or building support. Alternatively, the wall substrate may consist of a body panel or support member of a plane, boat, automobile or other vehicle. The wall substrate 3 can even take the form of a sidewall of a cargo container or the like. The wall substrate may be constructed in any manner known to those skilled in the art. For example, where the wall substrate forms part of a cargo container or a vehicle, the wall substrate may be a simple panel of plastic or metal which may or may not include reinforced ribbing. Where the wall substrate forms part of a building, it may be constructed of brick, concrete, wood, reinforced drywall, or other masonry.

The wall substrate 3 is then covered and protected by a reinforced wall covering 5. The reinforced wall covering includes one or more layers of the following: elastomeric coatings; reinforced grids, also referred to as fabrics, release agents, modified spackle coatings and intumescent coatings or additives. The elements are combined in various combinations depending upon the nature of the wall substrate being protected to provide the maximum cost effective manner for protecting the underlying wall substrate from a blast effect. With reference to Figs. 1 - 4, most reinforced wall structures 1 of the present invention will include application of a first elastomeric layer 7 to the wall substrate 3. Preferably, the wall substrate's surface is prepped by removing dirt and other materials including flaking paint, and by removing excess moisture. Suitable elastomeric materials include extruded thermoplastics, polyurea, polyurea-urethane, polyurethane, and mixtures thereof. However, a preferred product is polyurea provided

by BASF™ or a polyurea product sold by Line-X under the designation XS350. Depending on the polymer layer's purpose, the polymer layer will typically be prepared to a depth of 1/16" - 1/4".

The polyurea elastomers are considered preferable as they are very reactive, do not require a catalyst to cure and cure particularly fast, typically in the 5 - 15 second range. Polyurea also provides high elongation, high strength and modulus of elasticity. Polyurea is preferably applied using a spray applicator as shown in Figs. 1 and 7 which includes a manually controlled spray gun 29 which is connected to hoses 39, heaters 31, feed pumps 34, proportioning pumps 33 and a pressurized source 35 to supply appropriate hardeners 43 and resins 41. Typically using nozzle pressures of 2,500 - 3,000 psi, spray applicators such as provided by Graco, Inc. of Minneapolis, Minnesota supply approximately 30 cubic feet of elastomer material per minute.

The reinforced wall covering 5 of the present invention will preferably include one or more layers of a reinforced grid 13. With reference to Figs. 1 - 6, the grid will be affixed to the wall substrate or underlying elastomeric layer using an adhesive or pressure sensitive tape. The grid 13 includes vertically extending warp threads 15 and horizontally extending weft threads 17. The terms "vertical" and "horizontal" are intended to be used in the broadest sense to refer to the threads positioned to extend generally vertically or horizontally with respect to each other, and would thus include various combinations of cross stitching, weaves in varying directions, helical patterns and the like. With reference to Fig. 5, in a preferred embodiment, the grid 13 includes vertical and horizontal threads which include elastic cores 19 which are independently wrapped

with comparatively non-stretching fibers 21 made of carbon fiber, aramid fiber, steel strands, or other high strength low elastic filaments. The elastic core may be constructed of various materials including spandex, nylon or rubber. However, preferably the elastic core provides a significant elasticity to the overall grid structure.

After the grid structure 13 has been installed upon the wall, preferably an additional layer 9 of elastomeric material is applied to cover the reinforced grid of strands. The additional elastomeric layer is applied in similar manner to the first elastomeric layer 7 which was applied directly to the underlying wall substrate. In particular, the additional one or more elastomeric layers may be applied by spray, dip, trowel-on, or roll-on applications.

With reference to Figs. 2 - 4, where elastomeric layers are applied directly to an underlying elastomeric layer, preferably the reinforcing wall covering 5 includes a release agent 23 sandwiched between the respective elastomeric layers. The release layer may also be applied by dip, spray, trowel-on or roll-on application. The release agent may be any preferably nontoxic material which reduces the adhesion between the respective adjacent layers of elastomeric material. Suitable release agents include wax, oil, silicon or teflon based substances, though additional materials can be selected by those skilled in the art. In a first preferred construction, the release layer is applied to the center of the underlying elastomeric layer leaving a thin periphery uncoated. The additional elastomeric layer is applied providing predominant adhesion and affixation between the respective elastomeric layers at their peripheries. Alternatively, the release agent may be applied upon the underlying elastomeric layer's periphery or sporadically so

as to reduce the affixation of the elastomeric layers to one another. Preferably, the release agent provides some adhesion between the respective layers so as to maintain the overlying elastomeric layers in place without significant sagging or stretching due to the inherent weight of the material. However, in the event of a bomb blast, the release agent provides reduced adhesion to allow the respective elastomeric layers to shear with respect to one another and independently flex and bend so as to absorb the bomb effects. The separation of the elastomeric material into independent layers also allows each to deform independently so as to withstand greater deformation without fracturing or tearing.

Preferably, the reinforced wall system of the present invention provides for an aesthetic appearance. Various methods for providing a general pleasing appearance to the outside of the wall are available. With reference to Fig. 2, in a first preferred construction, the last few millimeters of the final elastomeric layer include an interspersed aggregate 25. The aggregate may be mixed into the resin or hardener material prior to application. Alternatively, the aggregate 25 may be fed directly into the spray nozzle for being sprayed within the elastomeric material upon a wall. Various aggregate materials may be utilized, such as sand, walnut shells, metal fragments or mixtures thereof. Moreover, the aggregate may be of various sizes, though a 30 - 60 grit size is preferred. The inclusion of an aggregate provides for a slightly bumpy surface so as to reduce the "plastic" appearance of the exterior elastomeric layer. The textured surface also provides for increased adhesion for the application of additional paints or coatings.

In an additional preferred embodiment, a modified "spackle" or joint compound is applied to cover the entire outer elastomeric layer. The modified spackle includes traditional spackle materials such as water, calcium sulfate, and/or limestone. However, preferably the modified spackle also includes an additional polymer adhesive such as an acrylic copolymer for additional adhesion to the underlying elastomeric layer. Suitable polymers and acrylic copolymers can be selected by those skilled in the art. The addition of the adhesive polymer provides for additional adhesion for affixing a spackle to the underlying elastomeric coating, whereas traditional spackle materials do not provide suitable adherence to an elastomeric coating.

The reinforced wall structure 1 also preferably includes an outer coating 27 for providing a desired color. The coating may include a fire retardant, such as an intumescent material which swells and is char-forming under fire conditions. The outer coating may be a traditional fire retardant paint which is applied in conventional manner. Alternatively, it may be an intumescent paint which is applied to a thickness of 20/1000" thick, such as those provided under the tradenames FireFree 88 or CKC F-268.

In still an additional preferred reinforced wall system, the outer modified spackle material or paint incorporates fire retardants, such as intumescent materials, fungicides, bactericides, or viruscides. Preferably, the modified spackle creates an anti-biological and/or fire retardant cloud upon seeing blast effects. Alternatively, the anti-germ, bacteria and viral materials may be incorporated into the intermediate elastomeric layers or release agent layers. The addition of these anti-germ, bacteria and viral materials provide additional protection in the event that a

terrorist adds a biological weapon into an explosive blast. Preferably, the anti-biological agents are sufficiently concentrated to minimize the effects of a biological agent within a terrorist explosion; however, not so concentrated or hazardous to result in additional harm to building occupants.

Various modifications of the reinforced wall system can be made without departing from the spirit and scope of the invention. For example, additional layers of reinforcement grids of strands and elastomeric layers may be added for additional protection against bomb blasts. Alternatively, where the threat of terrorism is particularly low, or where cost is a factor, the reinforcement grid and additional layers of elastomeric material may be eliminated. Examples of acceptable structures are listed as follows.

Example No. 1

As shown in Fig. 2, a preferred reinforced wall structure for protecting high threat and highly valuable infrastructure such as the Pentagon is provided. The reinforced wall structure 1 includes a wall substrate 3 of brick, concrete, wood, stucco, drywall, etc. The wall substrate is covered by a reinforced wall covering including three elastomeric layers 7, 9 and 11. After the wall substrate has been prepped by the removal of dirt and moisture, a first polymer layer 7 is applied to a depth of approximately 1/16" - 1/8" thick. A reinforcement grid 13 of strands is affixed to the first elastomeric layer by tacking the grid to the underlying elastomeric layer 7. Preferably, the reinforcement grid includes strands having a central elastic core wrapped helically by aramid strands shown in Figs. 5 and 6. After the reinforcement grid is affixed in place, a

second elastomeric layer 9 is sprayed upon the reinforcement grid. Preferably, the second elastomeric layer is applied to a thickness of 1/16" - 1/8" thick. Thereafter, a release agent 23 of wax, oil, teflon or silicon is applied to the center portion of the second elastomeric layer leaving only a periphery of a few inches of the wall substrate uncovered. A third elastomeric layer 11 is then applied to the reinforcing wall covering to a depth of 1/16" - 1/4" thick.

An aggregate 25 is interspersed into the third elastomeric layer within the final few millimeters of application to provide a textured coating. The third elastomeric layer is then painted with an outer coating 27. Alternatively, a drywall spackle material 27 incorporating polymer adhesives, intumescent agents and/or antibacterial agents is applied to cover the third elastomeric layer. The modified spackle material is then painted using a fire retardant paint according to the color schemes of the building.

Example No. 2

As shown in Fig. 3, a second reinforced wall system 1 of the present invention is provided which is considered particularly appropriate for protection of cargo containers, vehicle body panels and the like. The reinforced wall system 1 includes two elastomeric layers 7 and 9 and a layer of reinforcement grid of strands 13. A first elastomeric layer 7 is applied to the underlying wall substrate by dip or spray application. The reinforcement grid 13 is then affixed to the first elastomeric layer. Preferably, the reinforcement grid includes vertically and horizontally extending strands which have center elastic cores which are helically wrapped by aramid fibers. The reinforcing wall covering may be applied to the interior or exterior of a cargo

container, vehicle panel or the like. Moreover, the application of a modified spackle can be avoided since appearance is not a predominant feature. Instead, preferably the second elastomeric layer 9 is simply painted with a fire retardant paint 27 or the like.

Example No. 3

An additional reinforced wall system 1 is provided where the threat of an explosion is decreased, or where construction or cost considerations support lesser preventative measures. As shown in Fig. 4, the reinforced wall system includes two elastomeric layers 7 and 9 separated by an intermediate release agent layer 23. The reinforced wall system does not include a reinforcement grid. Instead, the elastomeric layers are to be 1/16" - 1/4" thick and provide significant protection to the underlying wall substrate.

The outer elastomeric layer may be painted or covered with a drywall modified spackle to provide a more aesthetically pleasing appearance. Fire retardant additives may be introduced into the modified spackle. Alternatively, the outer layer of the reinforced wall system may be painted with a fire retardant paint.

Although particular preferred embodiments of the present invention have been described herein, it is to be understood that variations may be made in the construction, materials and shape of the reinforced wall system without departing from the spirit and scope of the invention. Having identified the presently preferred best modes of practicing the invention, I claim: